Massachusetts Department of Environmental Protection

Technology Guide

MassCleanDiesel: Clean Markets Program

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Contents

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Introduction

Under the 2011 *MassCleanDiesel: Clean Markets Program*, the Massachusetts Department of Environmental Protection (MassDEP) is accepting grant applications to fund technologies to reduce air pollution from diesel engines that service wholesale markets, warehouses, and distribution centers in Massachusetts. Full or partial grants are provided for the purchase and installation of the following three types of diesel emission reduction technologies:

- **Auxiliary Power Units (APUs)**, idle reduction technologies that provide heating, cooling and electricity to long-haul Class 8 trucks, allowing engine owners to turn off the main truck engine during periods of extended idling.
- **Electric Transportation Refrigeration Units (eTRUs)**, in exchange for retirement of similar diesel units.
- **Retrofit Technologies**, pollution control equipment that is installed in the exhaust stream of a diesel engine. Diesel oxidation catalysts (DOCs) and active and passive diesel particulate filters (DPFs) will be offered under this program.

MassDEP will fund the following percentage portions of equipment, installation, mileage, and data-logging (if applicable) for the technologies:

Technology	**Program Financing Structure**	
	MassDEP Grant Allocation	***Applicant Cost Share***
APU Alone	50%	50%
APU + Retrofit Device	100%	0%
Retrofit Device Alone	100%	0%
eTRU	75%	25%

MassDEP will not fund costs associated with: 1) the destruction and scrappage of the trailer's existing diesel TRU; 2) the installation of electrical infrastructure to support eTRUs and active DPFs requiring regeneration panels; 3) the purchase and installation of retrofit technologies on APUs and diesel TRUs; 4) ongoing operations and maintenance costs for existing technologies, including filter cleaning; 5) fees for a third-party consultant or dealer hired by the grant recipient to coordinate the application or manage the grant-funded activities.

This guide describes the significant economic, health, environmental and social benefits of diesel emission reduction technologies and then focuses on each technology, its operational characteristics and maintenance requirements. Engine owners will need to weigh these factors in making their decision about which technology to install on their truck or trailer. Specific vendors and products are listed at the end of the document.

Economic, Environmental, Health, and Social Benefits

There are four distinct types of benefits associated with the technologies offered through the *MassCleanDiesel: Clean Markets Program:* 1) economic; 2) health; 3) environmental; and 4) social.

Economic Benefits

Participants in this grant program will realize significant long-term benefits through fuel savings and lower equipment maintenance costs by installing eTRUs and APUs on their trailers or trucks.

APUs shift the energy load of heating, cooling, and electricity from the main engine to the APU, reducing wear on the main engine and significantly lowering fuel consumption. The table at right shows the benefits of using an APU. In just one year, an engine owner can save over $7,300 in fuel costs.

APU Annual Cost Analysis

Activity	**Main Engine**	**APU**
Diesel Fuel [1]	$9,000.00	$2,250.00
Maintenance [2]	$1,200.00	$600.00
TOTAL	*$10,200.00*	*$2,850.00*
Annual Savings		***$7,350.00***
Cost of APU (est.)		$9,000.00
Required Cost Share (50%)		$4,500.00
Payback		***Less than 1 Year***

[1] Main Engine Idling: 1 gal/hr x 2,400 hr/yr x $3.75/gallon
APU: 0.25 gal/hr x 2,400 hr/yr x $3.75/gallon

[2] APUs require less oil and maintenance than the main engine

Similarly, eTRUs provide direct economic benefit by eliminating diesel fuel consumption and shifting the refrigeration power source from a diesel engine to the more economical electricity of a land-based power grid. ETRU owners can expect:

- *Lower Maintenance Costs* – Electric motors require minimal maintenance, compared to diesel engines.
- *Greater Reliability* – New electric motors are designed for years of trouble-free operation.
- *Lower Energy Costs* – Monthly electricity costs are expected to be about one-third of current monthly diesel fuel costs.
- *Reduced Administrative Burden* – Switching to electrically powered units will eliminate the need for fuel delivery scheduling and payments.

Electrification of refrigerated truck trailers used for cold storage is an extremely cost effective method to reduce diesel emissions. This program will provide funding for the replacement of old diesel-powered TRUs with new electric units with only 25% of the total cost borne by the

equipment owner.[1] Annual savings to the owner from replacement of an older diesel TRU with a new electric unit are projected at approximately $10,000. This savings will make up for the electricity infrastructure costs in a very short time.

In addition to preventing engine wear and tear and fuel savings, diesel emission technologies produce significant indirect, long-term economic gains by reducing the number of employee sick days, improving productivity, and lowering health care costs.

Environmental Benefits

Diesel engines emit both particle and gaseous air pollution. Diesel fine particle pollution (termed "fine PM") is composed of carbon soot and droplets of unburned fuel and lubricating oil. Gaseous diesel pollutants include carbon monoxide (CO), hydrocarbons (HC) and nitrogen oxides (NOx). HC and NOx react with sunlight to form ground level ozone, the main component in smog.

Diesel particles are a major cause of poor visibility in many parts of the U.S. Particles in the air scatter and absorb light, reducing the color, clarity and contrast of distant objects. In addition to affecting visibility, diesel particles cause ecosystem damage. Particles are carried over great distances by wind and then settle on ground or water. The effects of this settling include changing the nutrient balance in coastal waters and large river basins and making lakes and streams acidic; damaging sensitive forests and farm crops; depleting soil nutrients; and negatively affecting the diversity of ecosystems.

All technologies offered in the *MassCleanDiesel: Clean Markets Program* reduce diesel particles as well as other pollution that adversely affect the environment, as shown in the following Table:

Pollutant Reduction by Technology

Device	Pollutants (% Reduction)			
	PM	**NOx**	**HC**	**CO**
APU	10%-25%	89%-94%	0%	0%
eTRU	100%	100%	100%	100%
DOC	30%	0%	60%	60%
DPF	85%	0%	90%	90%

[1] Unit owners will be required to certify that the electric TRUs provided under this program will continue to operate within Massachusetts for a minimum of two years, and that owners will not sell, lease, or move the units to another state, and will perform maintenance and repairs as necessary to keep the units operational. As a condition of replacement, the diesel engines in the old units must be destroyed so that they cannot be re-used.

Health Benefits

Diesel exhaust has serious, detrimental effects on human health. Ultimately, all technologies included in this program are offered to reduce diesel exposure to at risk populations. Reduction of diesel emissions has a direct beneficial impact on the health and well-being of employees and those working or living in close proximity to a diesel vehicle or fleet. The health benefits include:

- *Reduced Health Risk* – With reduced emissions, workers and residents will experience reduced diesel related sickness and hospitalizations.
- *Reduced or Eliminated Exhaust Emissions* – Less diesel exhaust means cleaner air for market workers and nearby residents.
- *Reduced Exhaust Odors* – Less diesel exhaust means less odor, making for a more pleasant environment for market workers and nearby residents.
- *Reduced Noise* – eTRUs and APUs are significantly quieter than larger diesel engines.

Social Benefits

There are benefits to installing diesel pollution reduction technologies that are difficult to measure. Businesses that proactively install these technologies demonstrate to the community that they care about their employees and neighbors, demonstrating corporate stewardship and promoting good public relations. If leveraged properly, participation in this program will be seen as an act of social responsibility that may return intangible dividends in the future, including:

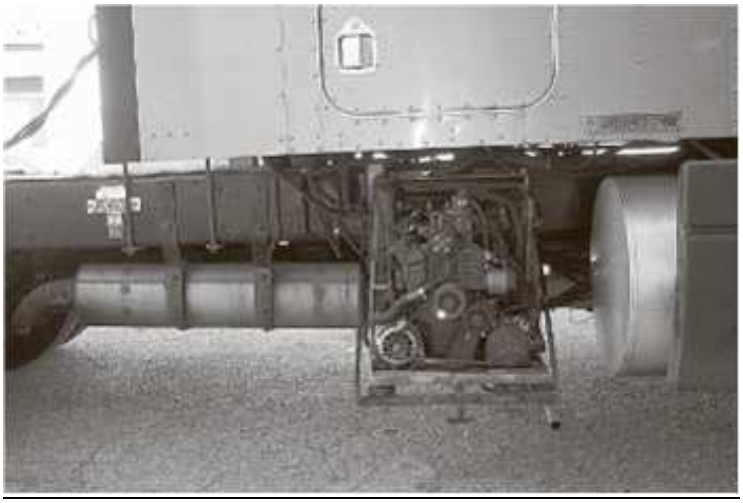
- *Improved Work Environment* – Reduced noise and exhaust fumes contribute to a healthier working environment.
- *Recognition by the Community* – City or state officials, environmental groups or non-profit organizations may acknowledge your company for taking steps to reduce your environmental burden.
- *Improved Quality of Life* – Reduced diesel exposure has direct and immediate health and welfare population benefits.

Auxiliary Power Units (APUs)

Operational Characteristics

An APU makes it possible to eliminate overnight idling that would otherwise be necessary to provide lighting, heating and cooling to the truck cabin. APUs are installed on Class 8 trucks, allowing the operator to shut down the main engine during periods of extended idling. APUs represent the most versatile method of power supply for auxiliary loads. The engine is sized to match the required load.

Auxiliary Power Unit Installed on a Truck



Source: Pony Pack, Inc.

Emission Reductions

In a study conducted by EPA,[2] it was determined that using an APU instead of idling the main engine would reduce NOx emissions by 89% to 94% and CO_2 by 52% to 81%.

Installation

APUs can either be stand-alone units that provide heated/cooled air directly to the vehicle cab, as well as a place to plug in standard electrical equipment, or APUs can have a high degree of integration with existing vehicle HVAC, battery charging and other systems. Installation varies from truck to truck but generally takes 5 to 16 hours to install.

Maintenance

APUs require much less maintenance than a main engine that otherwise must idle for hours at a time. Maintenance intervals are usually around 1,000 hours versus 500 hours for the main engine. The cost to maintain the APU is also less. Since the engine is much smaller than the main engine, APUs require less oil and fewer filters, further reducing costs.

Costs

Total unit costs for an APU range on the order of $6,000–$9,000 for on-road Class 8 trucks.

[2] See: "Study of Exhaust Emissions from Idling Heavy-Duty Diesel Trucks and Commercially Available Idle-Reducing Devices", USEPA Technical Report No. EPA-420-R-02-025, October, 2002.

Cost-Share Requirements

The MassCleanDiesel program will fund approximately 50% of the cost for the purchase and installation of an approved APU on a Class 8 truck with an engine model year 2006 or older. ***However, if an APU is purchased in conjunction with a retrofit device (for the main engine), both the APU and the retrofit device will be 100% fundable.*** MassDEP has prequalified technology vendors and APU technologies that will be funded by this program.

Verification

Only APU technologies verified under EPA's SmartWay Program are eligible for funding under MassDEP's program. SmartWay verifies technologies that have been evaluated to reduce fuel and emissions for use on trucks and locomotives. This list can be viewed at http://www.epa.gov/otaq/smartway/transport/what-smartway/verified-technologies.htm.

Electric Transportation Refrigeration Units (eTRUs)

Operational Characteristics

A transportation refrigeration unit (TRU) is a compact refrigeration system that is installed on a mobile or stationary trailer to cool the trailer's interior for storage and/or transport of perishable goods. Most TRUs are powered by small diesel engines that constantly run to keep temperatures in the trailer at the desired set-point. Over the course of a year, a diesel TRU may consume 3,600 gallons or more of diesel fuel, emitting a significant amount of diesel pollutants. An electric transportation refrigeration unit (eTRU) is plugged into a facility's on-site electrical infrastructure, thereby eliminating the use of diesel fuel.

Electric TRU and Power Supply

Source: M.J. Bradley & Associates, LLC

Emission Reductions

ETRUs have zero emissions, thereby reducing PM, NOx, VOC and CO by 100%. Eliminating these pollutants provide a better working environment for workers and local residents.

Installation

An eTRU is designed to be the same size as the existing diesel TRU. Installation is straightforward and requires very little or no modification to the trailer. The diesel unit is removed and a new high efficiency electric unit is installed. Installation of eTRUs will require access to electrical infrastructure. Participating TRU owners are responsible for arranging appropriate stationary power infrastructure; including completing required upgrades to their facility's existing electrical system. Each eTRU will require a 480 VAC/3-phase/ 30 amp or a 240 VAC/3-phase/ 60 amp outlet.[3] Electrical infrastructure improvements are estimated to cost between $1,000 - $10,000 per bay, depending on existing electrical service and the extent to which new circuits need to be wired.

Factors influencing infrastructure costs include:

1. The number of eTRUs to be installed (each eTRU consumes ~12 kWh).

[3] This is the standard configuration. As required, units may also be purchased that operate on 240 VAC/3-phase power. 240 VAC units will require a 60 AMP circuit.

2. The availability of excess electrical capacity at the facility.
3. The method of providing electrical service to the TRU (running power supply cord over the trailer to the TRU vs. installing permanent power supply at the TRU end of the trailer with buried conduit).
4. The location of the electrical service relative to the TRU (i.e., distance necessary to install electrical service).

Maintenance

The electric motors of eTRUs are designed for years of trouble-free operation. The eTRU system requires very little maintenance, with only a one-hour inspection service annually.

Costs

The *estimated* cost provided by pre-qualified vendors in this program to purchase and install an eTRU is $10,710 to $24,445. This does not include the cost to install new or upgrade existing electrical infrastructure.

Cost-Share Requirements

MassDEP will fund a maximum of 75% of the cost to purchase and install an eTRU. The applicant would be responsible for funding the remaining 25% of the cost. The applicant would also be responsible for funding the installation of new or an upgrade to existing electrical infrastructure.

Retrofit Technologies

Retrofit technologies refer to after-treatment devices that are installed downstream from the diesel engine's exhaust manifold. This program will fund diesel oxidation catalysts (DOCs) and active and passive diesel particulate filters (DPFs). These devices are mutually exclusive; therefore, only one or the other device may be installed on the eligible vehicle.

This grant program focuses on engine model year 2006 and older heavy-duty short and long haul trucks serving wholesale markets, warehouses, and distribution centers in Massachusetts. Starting in model year 2007, all trucks manufactured for use on public roadways were required to be equipped with a DPF; these 2007 and newer engines are ineligible for a retrofit device.

Verification

EPA and the California Air Resources Board (CARB) have established programs to verify emission reduction performance and durability of exhaust aftertreatment devices, so that consumers and businesses are assured of receiving the actual benefits claimed by the manufacturer. Both EPA and CARB put the retrofit devices through rigorous in-use and laboratory tests to ensure proper operation in the field. All devices funded through this program have been verified by EPA, CARB, or both.

Diesel Oxidation Catalysts (DOCs)

Operational Characteristics

A DOC is comprised of a stainless steel canister containing a honeycomb structure coated with a precious metal catalyst such as platinum or palladium. As exhaust flows through the DOC, the catalyst converts some of the unburned PM, HC, and CO into relatively benign by-products, mostly water and carbon dioxide.

Emission Reductions

DOCs can reduce PM by up to 30% and HC and CO by 60% each.

Diesel Oxidation Catalyst

Source: Cummins Emission Solutions

Installation

The DOC is installed in the exhaust stream of the vehicle. Typically DOCs are installed as direct replacements for the existing muffler, although in some cases they can be installed in series with the muffler. When installed, a DOC resembles a standard exhaust muffler, although a DOC may weigh slightly more due to the catalyst substrate. Installation time typically ranges from one to two hours.

Installed Diesel Oxidation Catalyst

Source: MassDEP

Maintenance

DOCs require virtually no on-going maintenance and typically last a minimum of six years.

Costs

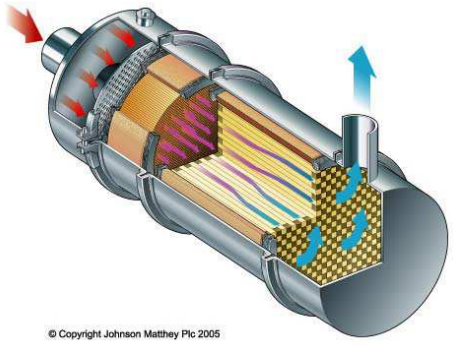
Installed DOCs offered in this program range from an estimated $790 to $2,965.

Cost-Share Requirements

Under this program, MassDEP will fund 100% of the cost for purchase and installation of a DOC.

Diesel Particulate Filters (DPFs)

Diesel Particulate Filter



Source: Cummins Emission Solutions

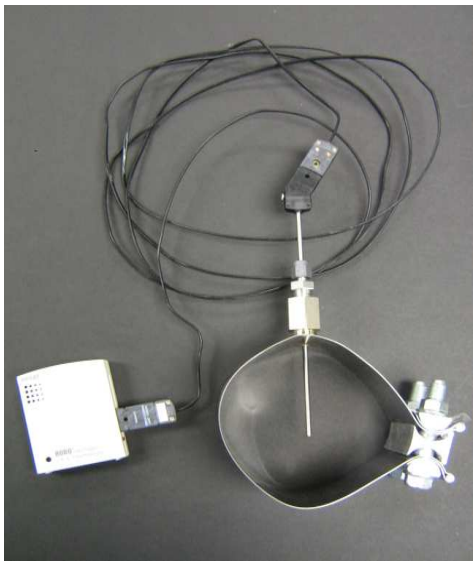
Operational Characteristics

A DPF can be either passive (working with the heat in the engine exhaust) or active (using an additional component to add energy to the exhaust to increase temperature). Both systems combine an oxidation catalyst with a porous ceramic, sintered metal, or silicon carbide filter in a metal container similar to an exhaust muffler. Gaseous engine exhaust passes through the porous walls of the filter section, while particles, both solid and liquid, are trapped on the filter walls. The filter bed is heated by either exhaust heat or some other heating mechanism, causing an oxidation reaction between the catalytic coating and captured particles. Unburned fuel vapor and CO are also oxidized, converting them into relatively benign by-products. This process is called regeneration.

Passive DPFs

Passive DPFs use exhaust heat to regenerate the filter. Therefore they require a minimum exhaust temperature of 240℃ to 290℃ for about 35% of total engine op erating time in order to trigger filter regeneration. If you decide you want a passive DPF, your vendor will need to install a temporary exhaust temperature data-logging device, shown left, on the vehicle to track its exhaust temperature over a week of typical operation. This temperature data will allow the vendor to understand whether a passive DPF is compatible with the way your vehicle is operated. If it is determined that a passive filter will not work in your application, an active DPF could be used. You could also install a DOC.

Exhaust Temperature Data-Logging Array



Source: MJ Bradley & Assoc., LLC

Active DPFs

Active DPFs use heat from other sources (typically fuel or electricity) to regenerate the filter bed; therefore they do not have any minimum exhaust temperature restrictions. Specific to this program, only two electrically regenerated DPFs are offered, the ECS Purifilter Plus and the Cleaire Horizon. The

ECS Purifilter Plus incorporates an electric heating element into the filter. When parked at a central location, the unit is hooked up to an electrical panel which turns on the heating element and blows hot air over the filter bed, causing oxidation of collected soot.

Engine Control Systems, Purifilter Plus™ Active DPF
(External Plug-in Regeneration Panel Not Shown)

Full Onboard Truck DPF Assembly

Inlet Section Electric Heating Element

Inlet Section Detail

Source: Engine Control Systems, Ltd.

Regeneration events for the active DPF must be performed while the vehicle engine is turned off. For an electric DPF to actively regenerate, it must be plugged into either a 240V or 480V AC power source. A regeneration panel is required that supplies the 240/480 voltage to the filter at a metered rate. The vendor or an electrical contractor will need to supply 240/480V AC power to the regeneration panel. Usually a cab-mounted indicator light will illuminate when a regeneration event is required; however, the manufacturer recommends proactive daily connection to the regeneration panel to minimize exhaust backpressure. The regeneration event usually takes 2 to 4 hours and requires that the vehicle remain inactive until complete.

Emission Reductions

Both passive and active DPFs achieve significant emission reductions. A DPF can reduce PM emissions by 85% or more and VOC and CO between 60% and 90%.

Installation

DPFs are slightly larger than the original muffler and weigh significantly more due to the filter substrate. Additional or more robust mounting hardware is required, and will be provided by the vendor. For passive DPFs, installation time typically ranges from six to eight hours per DPF. For active DPFs, installation requires at least 10 hours; this includes installation of the filter device and the electric regeneration panel. This installation time does not include electrical infrastructure upgrades necessary to bring power to the electrical regeneration panel.

Installed Passive DPF

Source: MassDEP

Maintenance

Installed devices typically last at least six years. DPF core elements require cleaning once every 12 to 24 months, depending on vehicle usage rate and engine condition. Cleaning is necessary to remove ash that builds up in the filter over time. Without periodic cleaning, backpressure will build up in the exhaust system, affecting engine performance. The DPF filter element must be removed from the vehicle to be cleaned.

As shown below, a backpressure monitoring system will be installed in the engine compartment and will indicate when maintenance is required. The monitoring system will activate a maintenance light when the backpressure rises above a certain threshold. The monitoring system will require a connection to the vehicle's 12/24 volt power system.

DPF Backpressure Monitoring System

Source: EPA

Filter cleaning requires a special machine and can often be done at a service facility for a fee of $200 to $400 per filter (some vendors can provide this service). The devices approved for this program are designed with a removable filter section connected to inlet and outlet sections with band clamps for easy removal for cleaning. This can be done in as little as half an hour. Typically, filter suppliers will swap filter sections upon removal to minimize vehicle down time.

Costs

The estimated cost provided by approved vendors in this grant program to data-log, purchase and install a passive DPF ranges from $6,825 to $20,655. The estimated cost provided by approved vendors in this grant program to data-log, purchase and install an active DPF ranges from $9,825 to $17,200. A regeneration panel must be purchased as well for the active DPF.

Cost-Share Requirements

Under this program, DPF technology, including installation is fundable at 100%. However, the vehicle owner assumes the on-going service and maintenance costs.

Technology Supplier Lists

These tables list the vendors that will be providing the equipment offered in this grant program.
*****Prices are estimated and may vary due to additional parts, labor or travel charges****.*

APUs

Vendor	Manufacturer	Product	Services Provided	Rating	Estimated Total Cost*
NE Detroit Diesel Allison	Carrier	ComfortPro PC 6011	Heating/Cooling/Power	12,000 BTU	$11,180
Shuster	Diamond Power Systems	DPS 6500	Heating/Cooling/Power	15,000 BTU	$7,870

ETRUs

Vendor	Manufacturer	Product	Rating	Single/Multi-Temperature	Estimated Total Cost*
NE Detroit Diesel Allison	Carrier	Vector 5100	59,000 BTU	Single	$17,400
NE Detroit Diesel Allison	Carrier	Electra	52000 BTU	Single	$13,975
Zanotti East	Zanotti	EFZ520	24,000 BTU	Both	$22,445
Zanotti East	Zanotti	EFZ 530	30,000 BTU	Both	$24,445
Zanotti East	Zanotti	MAS340	40-55,000 BTU	Both	$12,155
Zanotti East	Zanotti	SFZ258	24,000 BTU	Both	$11,655
Zanotti East	Zanotti	SFZ348	19,000 BTU	Both	$9,555
Zanotti East	Zanotti	BAS340	50-68,000 BTU	Both	$14,160
Zanotti East	Zanotti	PAS221	20-35,000 BTU	Both	$10,710

DOCs

Vendor	Manufacturer	Product	% PM Reduction	Estimated Total Cost*
MiltonCAT	Donaldson	Series 6100	20	$2,690
NE Detroit Diesel Allison	Donaldson	Series 6400	20	$2,410
NE Detroit Diesel Allison	Donaldson	Series 6100	20	$2,705
Shuster	ECS	AZ-25 Purimuffler	40	$2,710
Tri State Truck	Donaldson	Series 6100	20	$1,360
Tri State Truck	Cummins	Emissions Solutions	30	$1,360
Ward Clean Air	ECS	AZ-25 Purifier - AZ 31 Purifier	35	$790 – $2,565
Ward Clean Air	ECS	AZ-25 Purimuffler - AZ-31 Purimuffler	35	$1,260- $2,965

DPFs

Vendor	Manufacturer	Product	Type	% PM Reduction	Estimated Total Cost*
Tri State Truck	Cleaire	Longview	Passive	85	$7,225
Shuster	ECS	SC17 Purifilter	Passive	85	$6,825
NE Detroit Diesel Allison	Donaldson	LNF	Passive	85	$11,695 to $20,655
NE Detroit Diesel Allison	Donaldson	LXF	Passive	85	$14,430 to $20,655
Ward Clean Air	ECS	SC-06 Purifilter – SC-28	Passive	90	$6,870- $12,640
Tri State Truck	Cleaire	Horizon	Active	90	$8,030
Ward Clean Air	ECS	SCP-06 Purifilter Plus – SCP-28 Purifilter Plus	Active	90	$9,825 - $17,200